HISTORICAL PROBLEM NOTES
4CDU ATMOSPHERIC SYSTEM
Drawing D-308067 sheet 1 revision 2

1 C-1100 ATMOSPHERIC COLUMN

This column is carbon steel clad with T410 from the bottom head to 12' below tray 19 (just above tray 18, which is the 4 sidecut draw point). The temperature in this column has crept up over the years, so that now the cladding interface operates at approximately 600°F, above the threshold for hot H2S corrosion. During the 2005 survey, the temperature at the 4 sidecut draw point was found to be about 650°F and about 550°F at the 3 sidecut draw point. During the 2007 1st Q shutdown, no corrosion was noted at the interface. In the future, the cladding may need to be extended if corrosion does occur.

The top head was inspected for corrosion during the 1st Q 2007 shutdown and was found to be in good condition. However, the column trays have required frequent replacement. The top 2 trays required replacement during the 1995 shutdown due to corrosion and the top tray was replaced again during the 2002 shutdown (with T410SS this time). Then in 2007, the top 2 trays were again replaced, with the top tray (#48) being upgraded to Monel and the next tray down (#47) being replaced in-kind with carbon steel. This corrosion in the top of the column is most likely from NH4Cl. Per the Atmospheric Overhead Corrosion Control Best Practice (last revised in May 2005), the temperature at the top of the column should be both above 250°F and more than 25°F above the NH4Cl sublimation temperature to prevent corrosion in the upper part of the column. Prior to 2002, PED reports that this delta temperature had not been consistently maintained possibly leading to NH4Cl deposits and corrosion. As of 2003 when Critical Reliability Variables (CRV's) were being developed for 4CDU, PED was calculating the sublimation temperature three times per week based on Nalco water analysis and the pressure and the temperature has been maintained. However, the top two trays still required replacement in 2007 due to corrosion. The sublimation calculations/monitoring were to be included in the PED PMO capabilities.

Corrosion Under Insulation:
In 2005, external inspection of the column was completed and areas of damaged insulation were noted and repair recommended. As of 2007, this repair had not yet occurred. Also, some damaged insulation was found in 2004 and minor CUI was noted. Insulation and weather jacketing in the area were repaired.

Top of Column History:
In 1978 there was a fire in the top of the column from pyrophoric FeS deposits. There was no damage from the fire, but some corrosion noted on the top five trays of the column. In 1985, trays 19-21 were upgraded from carbon steel to T410 stainless steel. In 1992, the top ten trays were upset during an unscheduled shutdown. In 1995, these ten trays were replaced (trays 38-48). The top two trays were also found to be corroded at the time. In 2002, the top tray (48) was again corroded and was replaced with T410 stainless steel. Seven other trays were also

replaced with T410 stainless steel (trays 22-25 and 31-33). Trays 35-37 were replaced with carbon steel.

During the 1st Q 2007 shutdown, some of the trays were again replaced. Tray 48 was upgraded to Monel and tray 47 was replaced in-kind with carbon steel. At this time, the 2" and 2 1/2" diameter branches off of the distributor header at tray 48 were found eroded/corroded and were replaced in-kind. Additionally, trays 26-30 and 35-37 were replaced in-kind with carbon steel.

Also during the 2007 shutdown, the reflux inlet piping at tray 48 was replaced. It was found to be heavily corroded on the OD during a 2002 inspection.

Bottom of Column History:
In 1982 there was a leak in the transfer line. The failure was in a weld between the 5Cr transfer line and the clad inlet nozzle. In 1985 and 1988, the wear plate was found bulged and was repaired. See note 19 for additional information.

In 1995, trays 1-5 were replaced. A corrosion rate of 5-8 mpy was noted on tray 4. In 2002 and 2007, the wear plate was found to be bulged and the wear plate welds were cracked. Repair was deferred but clips were attached to the wear plate to prevent it from falling off during operation.

Coupons:
The 2006 ETC Metallurgy Review for 4 CDU recommended installation of a coupon rack to determine if the column cladding should be extended up higher in the future. Installation of an ER probe in the top of the column is also recommended to monitor corrosion rates. A coupon rack containing 5 coupons (410, carbon steel, Monel, Hastelloy C-276, and 316) was installed on Tray 47 during the 1st Q 2007 shutdown.

2 **C-1110 1 SIDECUT STRIPPER**

During the 1st Q 2007 shutdown, the 1st sidecut stripper required weld repairs to the ID on a large area. Corrosion, which was located at the top tray where it meets the shell, was attributed to under deposit corrosion. Deposits had been accumulating at the top tray, so the tray was removed at this time.

3 **C-1120 2 SIDECUT STRIPPER**

This column has a history of upset trays at each shutdown. Trays 3 and 4 were replaced during the 1991 shutdown. No significant corrosion has occurred except some corrosion was noted in shell course #2 during the 2002 shutdown, possibly requiring weld build up the next time the column is opened. This area was externally UT inspected in 2005. The corrosion rate seems to be in error, but further inspection is needed to confirm this. This column was bypassed for about 1 year in 2000.

4 C-1130 3 SIDECUT STRIPPER

In 2002, a corrosion rate of 37 mpy was noted in shell course 2. This rate is based on 1998 (the earliest available data) and 2002 data. However, the 1998 data is suspected to be erroneous. Further monitoring of this point in 2005 and 2006 showed a corrosion rate of 2.5 mpy.

5 C-1140 4 SIDECUT STRIPPER

This column has been out of service since 1991 because internal corrosion rates predicted the column would soon be below tmin. The trays were corroded thin at the last internal inspection in 1985. The column was stripped of insulation and externally inspected in 1998. Some CUI was noted, but no repairs were necessary. The column was externally coated at that time. The column will need a complete internal and external inspection if it is reused in the future.

6 F-1100 A/B ATMOSPHERIC FURNACE

Starting in about 1991, feed rates to this furnace were increased from 180 to 240 MBPD. Because of this increase, the bottom row of radiant tubes is suffering from external oxidation. Tube and hanger damage from overheating continues to be a concern. The furnace is IR scanned quarterly for hot spots on the tubes.

History Summary:

During the 1st Q 2007 shutdown, the A&B furnace tubes were inspected for wall loss and creep by Quest TruTec using "intelligent pigging" technology. No significant damage was noted.

In 2006, the south box north wall burner number 40 was impinging on the tubes. The burner was taken out of service. In 2005, PED noticed an increase in skin temperature (TI's) of 100°F in 3 months. Operations made changes to bring the temperature down. Also in 2005, flame impingement of the roof tubes was noted twice.

The furnace was internally inspected during the 2002 shutdown. Two tubes had oxidized due to overheating and portions were replaced. 26 radiant section hangers were replaced in the north firebox and 14 were replaced in the south firebox of F-1100A.

In 2002, new low NOx burners were installed. No major problems were noted during the 2000 and 1998 shutdowns. In 1995, the bottom radiant tubes in both A and B were replaced due to severe oxidation. The bottom row of radiant tube hangers was also replaced. Some roof tube hangers were oxidized to failure and replaced.

In 1991, all remaining HK-40 radiant roof hangers and the bottom row of radiant wall hangers were upgraded to HP-modified material. During start-up after the 1991 shutdown, the 7th pass of F-1100 B was stalled. Severe tube bulging, decarburization, and coking was found on all wall tubes and the lower row of roof tubes. These tubes were replaced with 5 Cr ½ Mo piping. Because piping material was used, some wall tubes now have less corrosion allowance than originally used. Since there is no significant tube corrosion, this reduction in corrosion allowance should not be a concern.

In 1988, the radiant roof furnace hangers suffered from short-term overheating due to fuel gas burner plugging problems. During the 1988 shutdown, some of the HK-40 hangers were replaced with type HP hangers.

7 <u>V-1102 DESALTER</u>

The desalter is internally lined with gunite for corrosion protection. In the past, damage to the gunite lining had been repaired each shutdown. Industry and Chevron experience has shown that corrosion of bare carbon steel in this service is not as severe as we once thought, so that maintenance of the gunite lining is no longer required.

The desalter had a history of poor performance and erratic pH control in the overhead system. During the 1991 shutdown, modified electrical grids and displacers were installed. This has resulted in better chloride removal and easier pH control of the overhead system. (See also note 20. The pH in the desalter is typically 5.5-6.5.

8 <u>V-1103 FLASH DRUM</u>

Historically this vessel has not been subject to significant corrosion. The last internal inspection was in 2002 and no significant corrosion was noted. However, the vortex breaker hold down tabs have failed twice (2002 and 1995). In 1995, the hold down tabs broke and the vortex breaker was inverted. This blocked flow through the outlet nozzle and the secondary feed pumps were starved and damaged as a result. The hold down tabs were found cracked and repaired again in 2002. A redesign should be considered. In 1991 this vessel was modified with new internals, nozzles and shell sections added to the vessel.

9 E-1101 A-D CRUDE FEED/ATMOSPHERIC COLUMN OVERHEAD EXCHANGERS

These exchangers can be severely corroded if the column overhead pH is not carefully controlled. They can see both low pH and high pH excursions on the tubeside. Low pH is especially a concern for the carbon steel channel, but can affect all tubeside components. High pH can affect the 70-30 Cu-Ni tubes.

The bellows have had many problems over the years, primarily due to mechanical damage when bundles are removed. Bellows were originally Inconel 625, but were changed to Monel in 1976. Monel has been used since, but replacements have been necessary multiple times (1978, 1991, 2001, 2002). A redesign with a tailpipe expansion bellows retainer should be considered. This would prevent bellows damage during bundle removal. El Segundo has completed this design change.

Exchanger History:
In 2006, leaks were found at the shell cover to tailpipe flange for both the A and C units. The leaks were clamped. In 2002, the tubes and tubesheet were found severely corroded due to pH conditions in all four exchangers. CUI of the shell was noted for all four exchangers. In A unit, the corrosion was most severe at the insulation support rings, where the shell was corroded to within 0.02" of tmin. This area was coated and left uninsulated. Also, in 2002, the bellows were replaced twice on all four units. During the 1st Q 2007 shutdown, the floating head tail pipe and bellows of the D unit was severely corroded due to chlorides. The tail pipe and bellows were replaced at this time.

Carbon steel tubes in all four units were replaced with 70-30 Cu-Ni in 1991. All four bundles were replaced in-kind during the 1st Q 2007 shutdown due to the corrosion found in 2002.

10 E-1103 CRUDE FEED/ 2 SIDECUT EXCHANGER

This exchanger has a history of bundle replacements due to corrosion and fouling. Bundles were replaced in 1976, 1977, 1980, 1998, and 2002. The bundle replacements were attributed to under deposit corrosion on the OD of the tubes. Deposits were a result of low water injection rates in the crude feed (injected to remove salts). An upgrade of materials will probably not address the issue. Process flow was redistributed in 2002 to solve this issue. As of 2007, flow is equally distributed through the primary train heat exchangers.

11 **E-1106 CRUDE FEED/ ATCR EXCHANGER**

In 2002, the shell was found to be near tmin due to corrosion under insulation (CUI). The corroded area was coated to prevent further corrosion. This area should be monitored. Otherwise, this exchanger has had no significant corrosion issues.

12 **E-1107 A/B CRUDE FEED/ATCR EXCHANGERS**

The tubes in these exchangers have been replaced in 1977 (twice), 1985, 1991, and 1998. The first two replacements were due to external corrosion under $CaSO_4$ deposits. Prior to 1978, low pressure water was injected ahead of E-1106 to keep $CaSO_4$ deposits in solution until they could be removed in V-1102. Since 1978, high pressure water is injected ahead of the E-1101's. This helps keep $CaSO_4$ in solution until it is removed in V-1102. The current bundle has been in service for 9 years with no wall loss noted during the 2007 shutdown.

13 **E-1113 CRUDE FEED/ 4 SIDECUT EXCHANGER**

In 1995, the bundle was replaced in kind with carbon steel. In 2001, the tubes were upgraded to 5 Cr due to hot H_2S corrosion. Corrosion was a result of increased sulfur content in the crude and higher temperatures in the 4 sidecut (now about 625-650°F here). No significant corrosion has been noted elsewhere on this exchanger.

14 **E-1117 1 SIDECUT STRIPPER REBOILER**

This exchanger is currently out of service and has been since approximately 1998. While in service, no significant internal corrosion of the exchanger was noted. However, inspection in 2002 found severe CUI in the out of service ABCR piping to the exchanger. If this exchanger is returned to service, a thorough inspection for CUI will be necessary.

15 **E-1127 VBCR/ 2 SIDECUT EXCHANGER**

This exchanger is currently out of service and has been since 1998. The bundle was retubed three times before 1995. The original 5 Cr -1/2 Mo bundle was replaced with T304 in 1988 due to hot H_2S corrosion. An internal inspection would be required if the exchanger were to be reused in the future.

16 E-1137 VBCR/ 3 SIDECUT EXCHANGER

This exchanger has been out of service since approximately 1998. In 1991, the channel on A unit was found severely corroded. If this exchanger is to be reused in the future, weld build up should be anticipated. Originally, the tubes were carbon steel, then were upgraded to 5 Cr-½ Mo in 1985 due to severe internal and external corrosion (hot H2S). The tubes were changed to T304 in 1988 again due to internal and external corrosion. This exchanger has a history of severe fouling.

17 E-1139 3 SIDECUT COOLER

Highly localized external corrosion of the top 2 rows of tubes was noted in 1999. The tubes were replaced in 1999. We need to monitor external tube corrosion in this and similarly designed air coolers. These rows of tubes are located under a shroud, which makes access very difficult for visual examination.

18 E-1163 A&B CRUDE FEED/ VACUUM RESID EXCHANGERS

In 1995, the tubes suffered under deposit corrosion due to lack of high pressure water injection in the crude feed (injected to remove salts which lead to fouling and corrosion). The bundles were changed from floating head to u-tube design. In 1998 the bundles were replaced due to corrosion suspected to be from lack of water in the crude feed. No corrosion was noted during the inspection in 2002. During the 1st Q 2007 shutdown, 1 tube of E-1163B had lost 27% wall thickness.

19 CRUDE FEED PIPING FAILURE @ CAUSTIC INJECTION QUILL

In 1990, the crude feed piping downstream of the flash drum failed from inadequate crude slipstream through the caustic injection quill. The corrosion mechanism was a combination of hot caustic and sodium sulfide (NaS2) corrosion. No caustic was injected from 10/90 to 10/91. During the 1991 shutdown, a new Monel injection quill was installed and caustic injection was resumed. Inspection during the 2007 shutdown revealed no issues.

Caustic is injected to convert chlorides in the crude to sodium chloride which is less likely to hydrolyze and form HCl. This helps control pH in the overhead system. For more details, see note 20, and CPM chapter 3100, section 3144.

20 ATMOSPHERIC TRANSFER LINE CORROSION

For the most part, this is a 5Cr- ½ Mo line. Some areas are striplined with T316L. The collection header is T316L.

The original 5Cr- ½ Mo line suffered naphthenic acid corrosion when highly corrosive crudes were used (neutralization numbers > 1.5). Highly corrosive crudes have not been used since the early 1980's. Naphthenic acid corrosion is very selective and attacks high velocity/turbulent areas such as furnace tubes, transfer lines and isolated areas of columns. See note 21 for general information on naphthenic acid corrosion.

Repairs to the piping consisted of weld overlaying corroded areas and in some cases striplining with T316L. The collection header was upgraded to T316L in 1982.

In 1985, the striplining showed multiple pinholes, but no repairs were required. The line was also inspected in 1988, 1995 and 2002 and repairs to the pin-hole leaks were deferred. The 2002 inspection noted areas where striplining seemed damaged, but it was not clear if product was accumulating under the striplining. UT did not find any areas of significant corrosion. In the 1st Q 2007 shutdown, oil was again found weeping out of the strip lining in the transfer line, but no bulging was noted. Consideration should be given to replacing the line in-kind in 2011.

21 ATMOSPHERIC COLUMN OVERHEAD SYSTEM

The overhead of this column has a history of corrosion. Currently, some areas require replacement at the next shutdown due to localized corrosion and leaks. Replacement piping, installed in 2007, is Hastelloy C lined. This loop is subject to severe HCl corrosion at low pH and NH4Cl corrosion at near neutral pH if NH4Cl salts condense and water is present. Because the velocity is high (about 100 fps), flow accelerated corrosion is possible. The most severe corrosion is from C-1100 to E-1101.

The overhead injection quill was replaced in November 2004 with a Schedule 80 (0.31" thick) Hastelloy C quill. During the 1st Q 2007 shutdown, up to 20 mils of corrosion was noted on the top surface of the quill (~10 mpy corrosion rate), further evidence that wet salts are being deposited on top of the quill.

Corrosion of the atmospheric column overhead exchangers (E-1101 A-D) and piping is a concern due to the presence of HCl. HCl is formed in the atmospheric furnace but does not result in corrosion until it is absorbed in the water that condenses in the overhead of the atmospheric column. To avoid severe corrosion, several control measures are taken:

- The crude is **desalted** to lower the amount of chlorides in the furnaces and overhead (V-1102).
- **Caustic** is injected into the feed to prevent hydrolysis of chlorides. Sodium chloride is formed which resists hydrolysis and leaves with the residuum. The amount of HCl going overhead is reduced.
- **NH3** is injected into the top of the atmospheric column, C-1100, and reflux stream to neutralize any HCl. The overhead pH is monitored and controlled to 6.5 to 7.2.
- **Wash water** is injected ahead of the E-1101's to ensure dilution of any HCl that condenses and to stabilize the pH. (This also helps prevent the formation of NH4Cl deposits.)

Corrosion is monitored onstream several ways:

- V-1100 water is tested for Fe, Cu and pH.
- 70-30 Cu-Ni and carbon steel corrosion probes are monitored. (The 70-30 Cu-Ni probe is ahead of E-1101 tubeside and the carbon steel probe is downstream of E-1101 tubeside.)

For more details on overhead corrosion control, see Atmospheric Overhead Corrosion Control BP (May 2005) and CPM Chapter 3100, section 3140.

22 NAPHTHENIC ACID CORROSION

When crudes with high naphthenic acid concentrations are used, severe corrosion can occur. The areas of most severe attack are the furnaces, transfer lines, and areas of columns exposed to highest neutralization number sidecuts (650°F-880°F TBP cuts). Turbulent or high velocity areas are attacked most severely. Temperatures as low as 350°F has been associated with naphthenic acid corrosion.

Carbon steel is susceptible to naphthenic acid corrosion and steels with up to 12% Cr are not more resistant. Usually T316L is resistant enough; sometimes T317L is needed for extreme conditions.

When high naphthenic acid crudes were used in the 4CDU, (late '70's, early '80's), corrosion occurred in both the atmospheric and vacuum transfer lines. Some areas were upgraded to T316L. If high naphthenic acid crudes are again used, material upgrades will be necessary.

Our current MOC process requires evaluation of new crude slates, including limiting the TAN of crude feeds to < 0.3 KOH/g (or < 1.5 for draw streams). This prevents naphthenic acid corrosion since this unit is not alloyed for higher naphthenic acid service.

For more details on naphthenic acid corrosion in crude units, see CPM Chapter 3100.

23 HOT H2S CORROSION

Hot H2S corrosion is a potential problem in carbon steel piping exposed to H2S at temperatures above 550°F. Increasing the chromium in the steel will increase resistance to hot H2S corrosion. Over the years, the temperature in various parts of the plant has crept up, so that areas that were originally below this threshold are now above. Increased UT inspection of these areas is justified. If corrosion is found, consider upgrading to higher chromium alloys, like 5 Cr - ½ Mo. One area of concern is the atmospheric column itself, where the cladding termination point now operates at about 600°F. See note 1 for details. Some other specific areas of concern, where increased corrosion may occur, are discussed below.

NUMBER 4 SIDECUT PIPING

This piping is currently carbon steel, but operates above the threshold for hot H2S corrosion. Corrosion rates are being monitored. The highest corrosion is downstream of the pumps (P-1148 and P-1149) due to high velocities. During the 1st Q 2007 shutdown, the piping between P-1149 and E-1113 was upgraded to 9 Cr and a guided wave transducer was installed in the carbon steel portion to monitor for corrosion on-line. We should continue to monitor carbon steel piping elsewhere in this sidecut system for hot H2S corrosion.

ATMOSPHERIC COLUMN BOTTOMS PIPING

Some of the 5 Cr piping operates at temperatures above 650°F, so sulfidation is a concern (we would use 9 Cr for new construction). Currently there is no history of significant corrosion of the 5 Cr piping. Corrosion is especially a concern in high velocity areas. Such areas should be inspected for potential erosion/corrosion.

24 PIPING CIRCUITS AND EQUIPMENT SUBJECT TO CORROSION UNDER INSULATION

Corrosion under insulation (CUI) can occur in insulated piping/equipment that operates below 300°F. Damage to the insulation weather jacketing allows water to enter and corrosion results. Equipment/piping that operates intermittently or cycles between hot and cold is especially susceptible. There are a few areas in the unit where CUI of piping has been found and replacements were completed during the 1st Q 2007 shutdown. In general, the most problematic portion of the plant is that which is exposed to the cooling water tower drift. See also mention of CUI/external corrosion of equipment in notes 1, 2, 10, 13 and 15.